TRACE FOSSILS FROM THE UPPER CARBONIFEROUS JERICHO FORMATION, CENTRAL QUEENSLAND

ALEX G. COOK AND KERRIE BANN

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A new trace fossil assemblage from lacustrine deposits of the Upper Carboniferous Jericho Formation, Joe Joe Group, Galilee Basin, Queensland, is described; it is similar to the Umfolozia ichnocoenosis found in other parts of Gondwanaland during the Late Carboniferous to Early Permian. The assemblage comprises exclusively of bedding-parallel tracks interpreted as arthropod locomotory traces, mainly *Tasmanadia gluessneri* ichnosp. nov., and *Alphaichnus alphaensis* ichnogen. et ichnosp. nov. Other new taxa are *Isopodichnus queenslandensis* ichnosp. nov., *Rusophycus devisi* ichnosp. nov. and *Wadeichnus maryae* ichnogen. et ichnosp. nov. ❐ *Trace fossils, Carboniferous, arthropod trails, Queensland.*

Alex G. Cook & Kerrie Bann, Queensland Museum, PO Box 3300, South Brisbane 4101, Australia; 10 September 1998.

Delicate and diverse trace fossil assemblages are known from Late Carboniferous to Early Permian of Gondwanaland, most notably the Dwyka Series, South Africa (Savage, 1971; Anderson, 1975, 1976, 1981), South America (Rocha-Campos, 1967; Aceñolaza & Buatois, 1991, 1993; Buatois & Mangano, 1993, 1994, 1995) and Australia (Chapman, 1929; Glaessner, 1957). Uniformity in these Gondwanan ichnofaunas allows recognition of inter alia Umfolozia, Isopodichnus and Mermia ichnocoenoses (Aceñolaza & Buatois, 1993) which are useful biogeographic and broad biostratigraphic indicators, as well as reflecting widespread glacial conditions or their onset. This paper is concerned with well-preserved trace fossils from shallow quarries of the Jericho Formation along the Sedgeford-Alpha Rd, SSE of Alpha, central Queensland (Queensland Museum Locality QML993).

The Jericho Formation is a dominantly fine-grained, siliciclastic unit forming part of the Joe Joe Group of the Galilee Basin. The unit was formally defined by Gray & Swarbrick (1975) who noted arthropod trails and suggested a lacustrine depositional environment in association with periglacial conditions. Biostratigraphic control on the Joe Joe Group was reviewed by Jones & Truswell (1992) who placed the Jericho Formation in the latest Carboniferous (Stephanian), postdating the onset of glaciation. In order to elucidate the depositional context for these trace fossils we examined recovered core from the same sequence.

DEPOSITIONAL SETTING

Examination of interval 770-740m in GSQ Jericho No. 1 (see Swarbrick, 1974: fig. 2) revealed a fining upward sequence, interpreted as a deepening alluvial to lacustrine environment (Fig. 1). At the base of the unit, unbioturbated, medium- to coarse-grained pebbly sandstone represents alluvial deposition. Above, the sequence grades to fine-grained sandstone with a *Macaronichnus* ichnofabric and possible escape traces, which we interpret as a deltaic environment. The sequence grades progressively into a bioturbated, interbedded sandstone and siltstone unit with sinaeresis cracks, contorted bedding and flame structures, possibly reflecting influx of sediment due to storms or seasonal input in a lacustrine environment. The upper portion of this unit is composed of pinstriped siltstone and very fine-grained sandstone with *Tasmanadia*. This part of the sequence we interpret to represent seasonal varves. The trace fossil assemblage is interpreted as a Rusophycus ichnofacies. The top 7.5m of the section contains bioturbated, interbedded very fine-grained sandstone and siltstone and reflects deposition in a distal, quiet lacustrine environment. The sequence is overlain by a series of prograding deltaic deposits.

RUSOPHYCUS ICHNOFACIES. In this study the eponymous ichnogenera are not italicised (following Bromley, 1996), because it is a facies and not an ichnotaxon that is under discussion (this is in line with the usage of taxa in biostratigraphical zones, e.g. Bifrons zone).

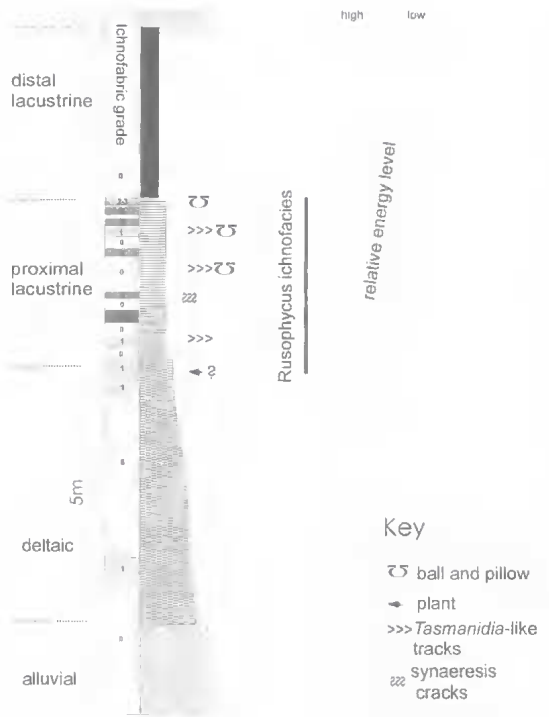

FIG. 1. Graphic log of GSQ Jericho No. 1 interval 770-740m, showing relative depostional energy, interpreted depositional environments and ichnofabrics adapted from Taylor & Goldring (1993).

This assemblage falls into the Rusophycus ichnofacies that was suggested tentatively by Bromley (1996: 249) to represent a freshwater (fluvial and shallow lacustine) ichnofacies dominated by Repichnia and Cubichnia.

In the Jericho Formation the Rusophycus ichnofacies is characterised by Repichnia, Cubichnia and Praedichnia (Table 1).

Aceñolaza & Buatois (1993) reviewed late Palaeozoic trace fossil assemblages of Argentina and identified four ichnocoenoses pertaining to differing lacustrine and fluvial sedimentary facies. They regarded the Umfolozia ichnocoenosis as representing arthropod activity within a shallow lake, and the Isopodichnus ichnocoenosis as representing activity within ephemeral, shallow pools, and channel and floodplain deposits. The Queensland material belongs within an Umfolozia ichnocoenosis, with arthropod crawling traces dominant. Keighley & Pickerill (1996) reviewed the interwoven taxonomic status of *Isopodichus*, *Rusophycus* and *Cruziana*, and provided a convincing argument against retaining *Isopodichnus*, placing ribbon like members of that taxon in *Cruziana*, and bilobate coffee-bean shaped members within *Rusophycus*. However Trewin (1976), Pollard (1985) and Aceñolaza & Buatois (1993) pointed out that *Isopodichnus* is generally smaller, with flaring ends. Furthermore the genus has a significant ecological and stratigraphic utility, and is here retained.

FUNCTIONAL INTERPRETATION. The absence of body fossils associated with the assemblage makes identification of the track-maker(s) difficult. The biserial nature of many of the traces indicates that they were made by arthropods. In *Wadeichnus*, interpreted antennae marks strengthens the arthropod identification. Groove markings on *Isopodichnus queenslandensis*, interpreted to have been made by telson drag, and the presence of paired scratch marks suggestive of at least 5 pairs of appendages on the related *Rusophycus devisi*, throws some light on the organisms responsible. The bifurcate distal appendage marks in *Alphaichnus* indicate that appendages were in the equally biramal (primitive) state, possibly representing activity of syncarid crustacea.

Terminology follows Osgood (1970) for 'trail', 'track', 'pair' and 'imprint'. 'Distal' and 'proximal' refer to the distance from the axis of the trace fossil, 'medial' pertains to features within the axial zones of tracks and 'lateral' to those in the marginal zones. Most material is preserved in hyporelief and all descriptions should be read as such. No attempt is made to establish higher order systematics.

SYSTEMATIC PALAEOICHNOLOGY

Isopodichnus Bornemann, 1889

TYPE SPECIES. *Isopodichnus problematicus* Bornemann 1889, from the Triassic of Germany.

REMARKS. *Isopodichnus* is a problematic ichnogenus, and has been variably placed in *Rusophycus* and *Cruziana*, with considerable taxonomic confusion, further obfuscated by well known intergradation between the three ichnogenera (also see below). Full accounts and differing opinions on its resolution are given by Osgood (1970), Hantzschel (1975) Keighley & Pickerill (1996) and Bromley (1996). The problems are intertwined and we do not propose to resolve this significant controversy. Bromley (1996: 184) provided the most accurate summary of this nomenclatural debate: 'I cannot see how *Isopodichnus* can be considered available other than a muddled junior synonym of both *Cruziana*

TABLE 1. Ethological classification of ichnotaxa described from the Jericho Fmn near Alpha.

Ethological classification	Ichnotaxon	Figure numbers
Repichnia	*Isopodichnus queenslandicus*	Figs 2A,B, 13B
Cubichnia	*Rusophycus devisi*	Fig. 3
Repichnia	*Tasmanadia glaessneri*	Figs 6, 7
Repichnia with Praedichnia	*Wadeichnus maryae*	Fig. 4
Repichnia with Praedichnia	*Alphaichnus alphaensis*	Figs 8, 9, 10A, 12, ?10B,C
?Fugichnia	Indet. sweep and scurry marks	Fig. 13D
?Praedichnia	Indet. paired appendage marks	Fig. 12

and Rusophycus'. The taxonomic stand of Keighley & Pickerill (1996) would have *Isopodichnus queenslandensis* within *Cruziana*. We retain *Isopodichnus* here as a genus-of-convenience awaiting resolution of the tripartite nomenclatural confusion. We note the considerable difference in the classic Early Palaeozoic *Cruziana* morphology and this material. The dichotomy between type specimens of *Cruziana* and those of *Isopodichnus* must be further investigated.

Isopodichnus queenslandensis ichnosp. nov.
(Figs 2A,B, 11 (part), 12B)

ETYMOLOGY. From Queensland.

MATERIAL. HOLOTYPE: QMF32233. PARATYPES: QMF34026, 39062 all from QML993.

DIAGNOSIS. Exclusively elongate and continuous *Isopodichnus*.

DESCRIPTION. Straight, gently curved or weakly sinuous ribbon-like trail, up to 7mm wide consisting of (in hyporelief) 2 parallel marginal longitudinal furrows and a central (axial) channel containing up to 6 subparallel longitudinal striae. Axial channel occupying slightly over ½ track width, with numerous fine longitudinal threads and a weak central ridge deviating from the mid-line along the length of the trail. Outermost longitudinal ridge in the axis with sporadic but numerous oblique, short striae. Marginal ridges with fine obliquely transverse striae, extending sub-perpendicularly beyond the edge of the trail. In some specimens these striae bifurcate, particularly as the trail shallows. There are numerous tiny (1-2mm wide) examples of the track (Fig. 9, large arrow) preserved in epirelief, the marginal parts of the track are slightly more pronounced than in larger specimens.

REMARKS. The central threads represent the drag marks of a telson with furcae, with the sporadic striae representing setae on the furcae. Short imprints on the edge of the track represent appendage marks. The relative depth of the track reflects the softness of the muddy substrate. The elongate nature of the trace and the internal striae separate this ichnospecies from material figured as *Isopodichnus osbornei* Glaessner, 1957: pl. 10, fig. 2a,b (partim); fig. 3, pl. 11 figs 1-3) from the Carboniferous near Seaham, NSW. The holotype of *Isopodichnus queenslandensis* is associated with *Rusophycus*. Smaller representatives of this taxon are interpreted as representing juveniles.

Rusophycus Hall, 1852

TYPE SPECIES. Significant problems with the nominate type ichnospecies are still to be resolved (Keighley & Pickerill, 1996).

REMARKS. Osgood (1970) restricted *Isopodichnus* Bornemann to small *Rusophycus*-like imprints of non-trilobite origin as well as to those of trilobite origin. Hantzschel (1975) suggested that *Rusophycus* be restricted to identifiable trilobite resting traces based on a genetic and stratigraphic methodology rather than an ethological/morphological approach. Use of *Isopodichnus* for small short traces was discussed by Glaessner (1957), Osgood (1970), Birkenmajer & Bruton (1971) and Hantzschel (1975). Keighley & Pickerill (1996) argued against *Isopodichnus* and placed bilobate coffee-bean shaped members in *Rusophycus*. Buatois & Mangano (1993) followed this using *Rusophycus* for non-marine, late Palaeozoic traces with this short bilobate morphology.

In the Alpha material *Isopodichnus queenslandensis* and *Rusophycus devisi* are associated and intergrade (Fig. 3C).

Rusophycus devisi ichnosp. nov.
(Figs 3, 7A (part))

ETYMOLOGY. For C.W. De Vis, who described the first trace fossils from Queensland (De Vis, 1911).

MATERIAL. HOLOTYPE: QMF32232. PARATYPES: QMF34026 (several specimens), 34090, 34069 (several specimens), all from QML993.

DIAGNOSIS. Small, elongate longitudinally subsymmetrical to irregular bilobate trace, showing at least 5 curved paired ridges in hyporelief within each lobe.

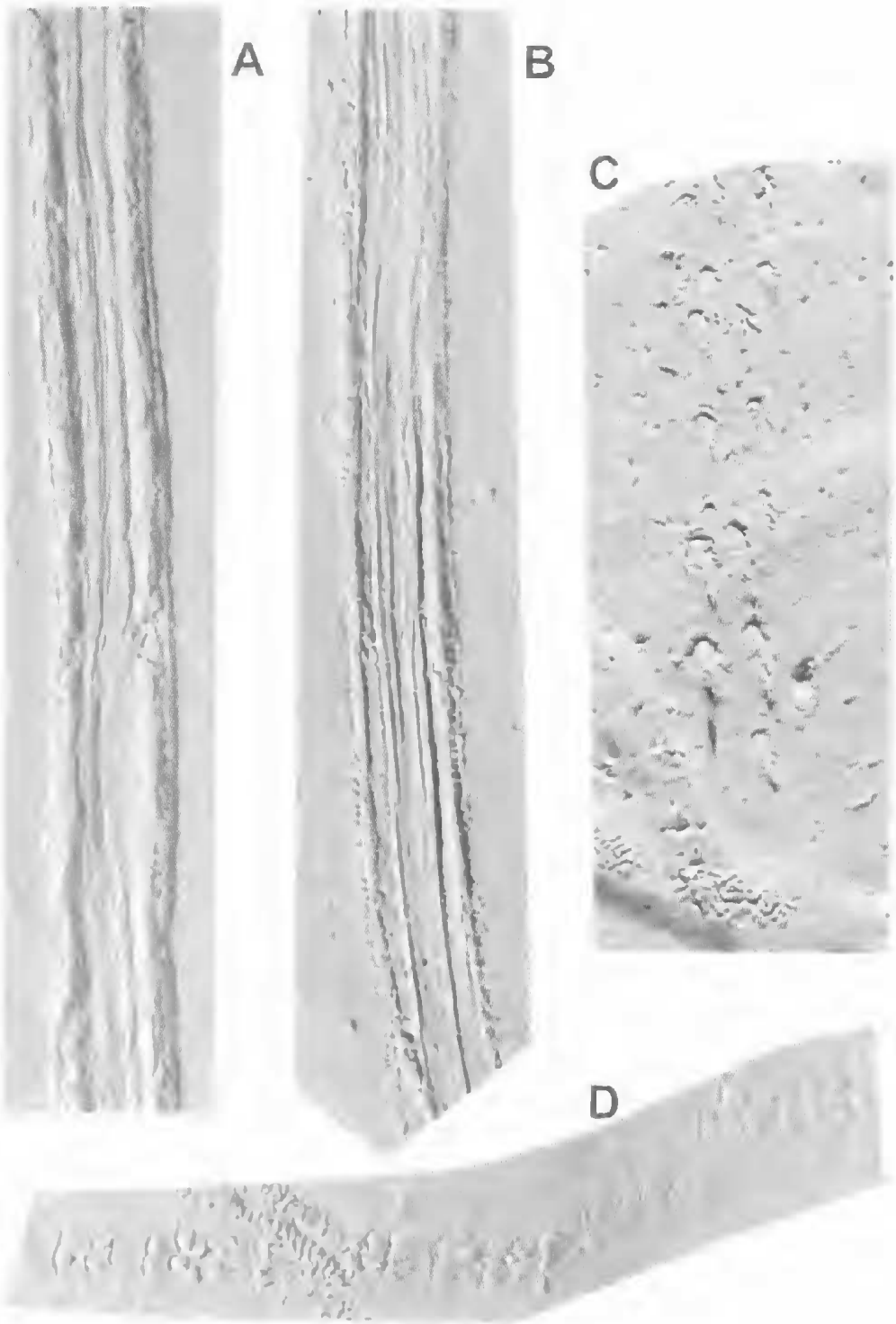

FIG. 2. A,B, *Isopodichnus queenslandensis* ichnosp. nov.; A, QMF34026 ×2; B, F32233 holotype ×2. C,D, *Wadeichnus maryae* ichnogen. et ichnosp. nov.; C. F34065 ×1; D, F39061 ×1.

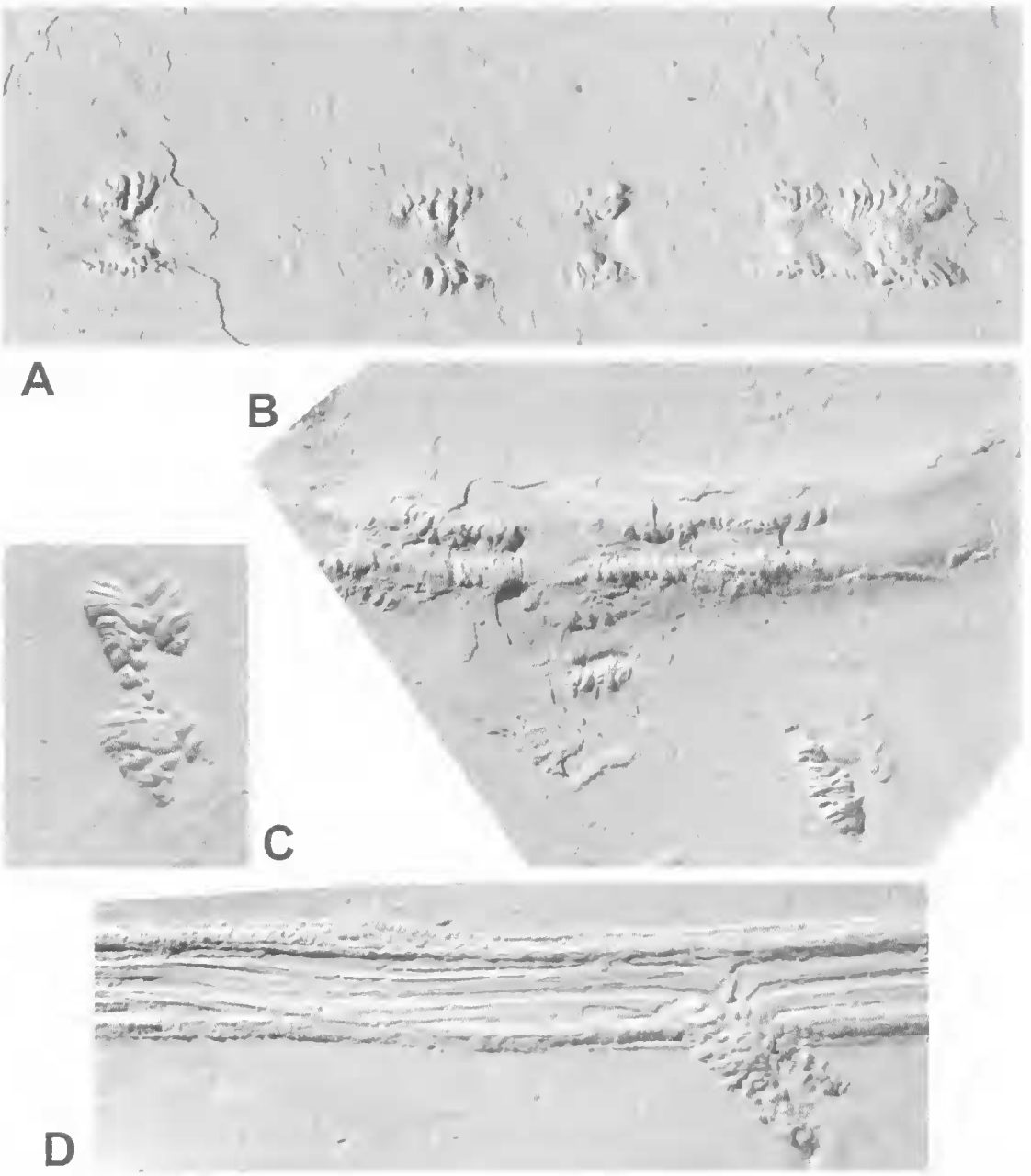

FIG. 3. *Rusophycus devisi* ichnogen. et ichnosp. nov.; A, QMF32232 holotype ×1; B, F34026 ×1; C, F34026, another track on of same slab; D, F32233, *Rusophycus devisi* ichnogen. et ichnosp. nov. in association with *Isopodichnus queenslandensis ichnosp. nov.* ×1.

DESCRIPTION. Small trace up to 11mm wide and 13mm long, 2 lobes subsymmetrical about a midline or irregular. Each lobe with at least 5 arcuate transverse ridges of which some are slightly divergent. Midzone of trace with an arcuate depression in hyporelief.

REMARKS. QMF32232 has 5 parts to this trace, 2 of which are coalesced (Fig. 3A) representing saltation-style locomotion between short resting traces. QMF34026 has 2 small asymmetrical specimens and an undertracked specimen of a transitional trace between *Rusophycus* and

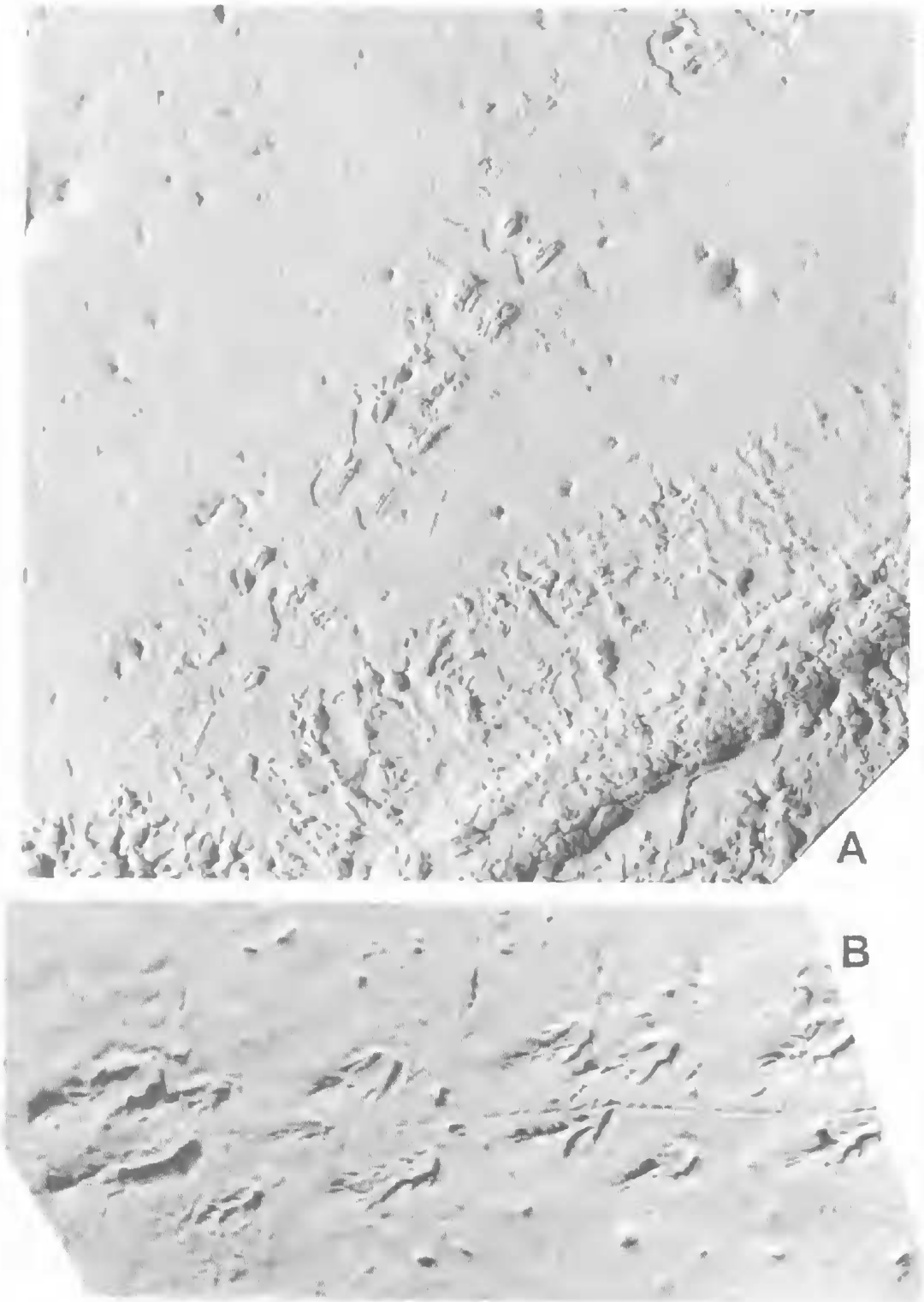

FIG. 4. *Wadeichnus maryae* ichnogen. et ichnosp. nov. A, holotype QMF39063, ×1; B, F39065, ×2.

Isopodichnus (Fig. 3B). QMF32233 shows *Rusophycus* in association with *Isopodichnus* (Fig. 3D) where the track may have been utilised twice by the same type of trace-producing organism. Other specimens are associated with *Tasmanadia*.

Tasmanadia Chapman, 1929

TYPE SPECIES. *Tasmanadia twelvetreeensis* Chapman, 1929 from the Upper Carboniferous Wynyard Tillite, Tasmania.

REMARKS. Chapman (1929) erected *Tasmanadia* for purported Cambrian annelid body fossils, reinterpreted to be Carboniferous arthropod tracks by Glaessner (1957) and Gulline (1967). Bromley & Asgaard (1979) regarded *Tasmanadia* as a junior synonym of *Diplichnites* but contrarily indicated significant differences in the fine morphology of the tracks; their extreme 'lumping' view where many arthropod track genera were synonymised is not here adopted.

Tasmanadia glaessneri ichnosp. nov.
(Figs 6, 7A (part))

ETYMOLOGY. For the late M. F. Glaessner.

MATERIAL. HOLOTYPE: QMF39069. PARATYPES: QMF32229, 34054, 34060, 34065, 34081, 34083, 34088, 34090, all from QML993.

DIAGNOSIS. Biserial track 8-11mm wide, of 2 near-symmetrical rows of fine ridges, nearly perpendicular to the track axis, in close, slightly divergent pairs.

DESCRIPTION. Track biserial, elongate, gently curved, of near symmetrical rows of fine ridges in hyporelief, 8-11mm in total width, with 3-4mm between inner ends of rows of ridges. Fine ridges in closely spaced pairs diverging slightly or subparallel, individually very weakly arcuate, perpendicular to the track axis. Sporadically finer, more strongly divergent appendage marks marginal to the track pairs. Rare lengthwise, but short marks along the track axis. Some specimens over 500mm long.

REMARKS. The paired track marks indicate *Tasmanadia*. This material is differentiated from the type species by the greater divergence of the distal ends of the ridges forming the track pairs. *Permichnium* Guthörl, 1934 has slightly more divergent paired ridges, but they emerge from subcircular foot impressions, lacking in this material. *Maculichna* Anderson, 1975 possesses rows of paired spots, and lacks the paired divergent elongate marks of this material.

FIG. 5. Interpreted schema for *Wadeichnus maryae* ichnogen. et ichnosp. nov. based on holotype specimen, ×2.

Umfolozia Savage 1971 also possesses a series of paired and complexly arranged dots in contrast to the simplicity of this material. Specimens of this ichnotaxa grade into *Rusophycus* and *Alphaichnus*, the latter evidenced by the rare occurrence of fine marks adjacent to the paired ridges. Shallow undertracking suggests greater substrate firmness than for *Alphaichnus* and *Isopodichnus*.

Alphaichnus ichnogen. nov.

TYPE SPECIES. *Alphaichnus alphaensis* ichnogen. et sp. nov.

DIAGNOSIS. Biserial, gently curved, to straight trace consisting of subsymmetrical rows of up to three sets of paired ridges which are distally

FIG. 6. *Tasmanadia glaessneri* ichnosp. nov., specimens from slab QMF34090. A, overprinted hyporelief specimens and indeterminate sweep traces (small arrows). ×1; B, further detail same specimen ×1.

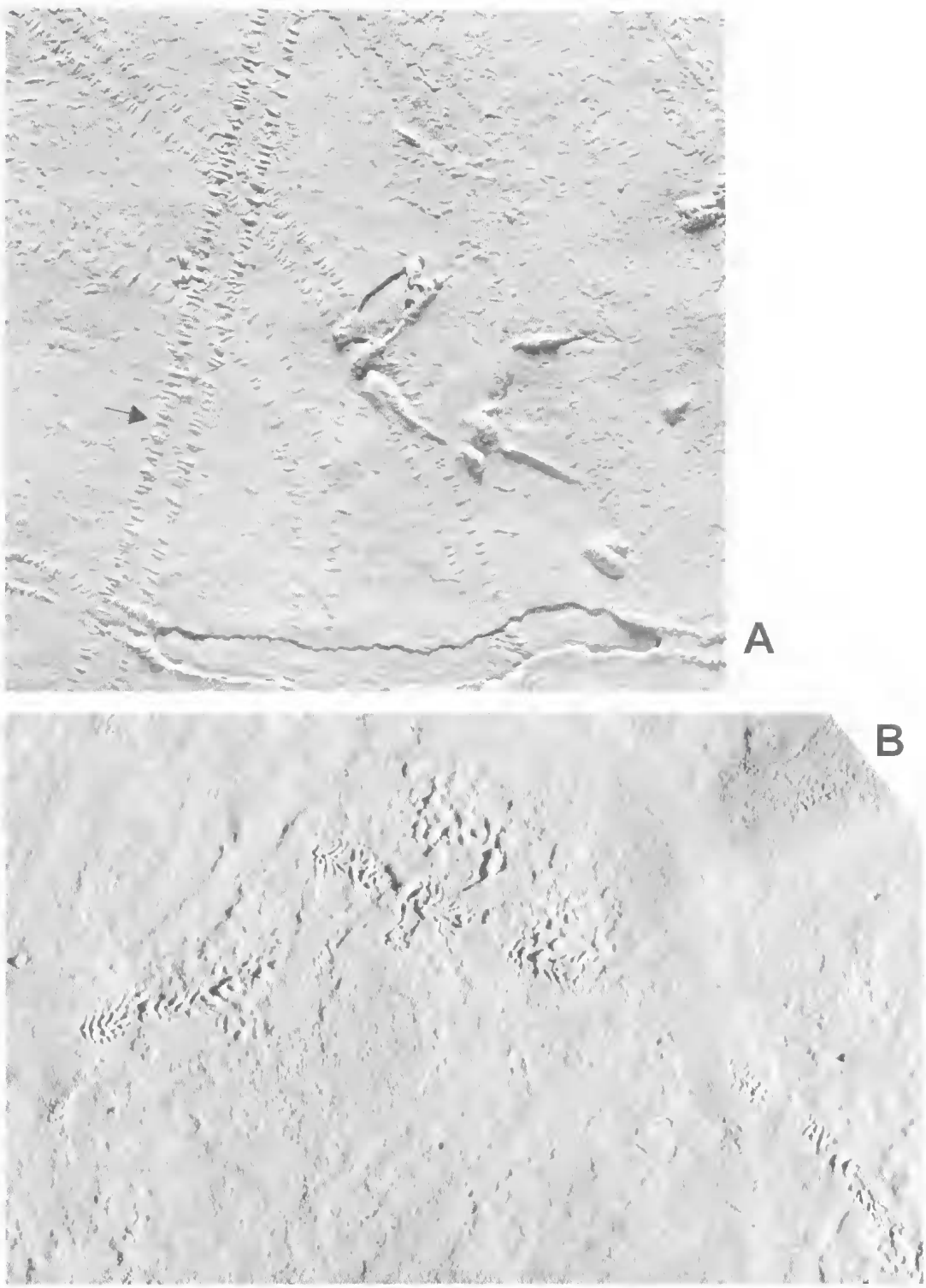

FIG. 7. A, *Tasmanadia glaessneri* inchosp. nov., QMF39069 holotype, (arrow) with associated *Rusophycus devisi* ichnosp. nov. and indeterminate traces ×1. B, indet. appendage marks, QMF34067 ×2.

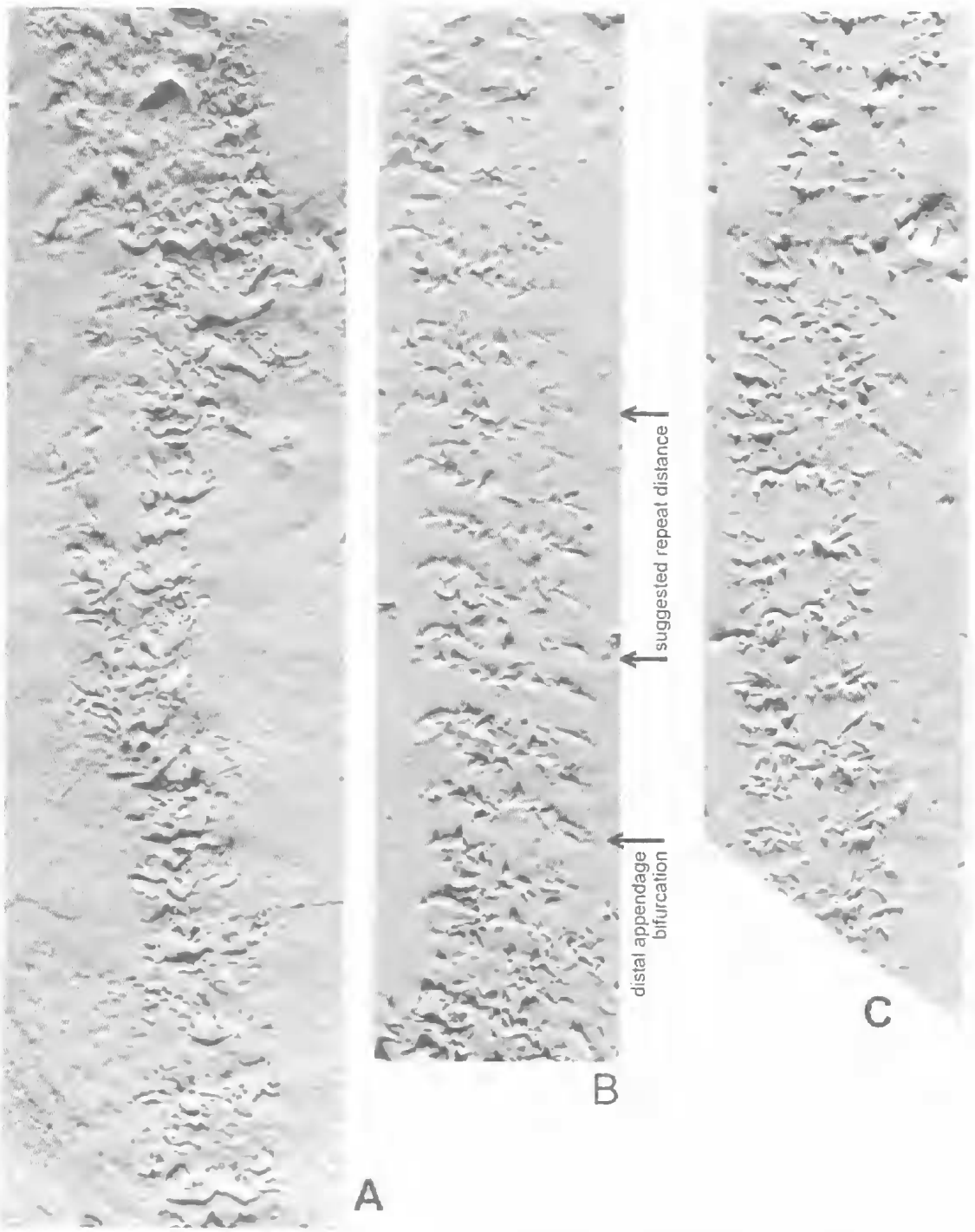

FIG. 8. *Alphaichnus alphaensis* ichnogen. et ichnosp. nov. QMF34068 ×2. B, holotype F34084 ×2; C, F34084, track on different part of same slab ×2.

branched and have short fine striae. Axis with or without arcuate ridges or transverse oblique ridges.

Alphaichnus alphaensis ichnogen. et sp. nov. (Figs 8-11)

ETYMOLOGY. From the town of Alpha.

MATERIAL. HOLOTYPE: QMF34084. PARATYPES: QMF32231, 34033, 34039, 34043, 34057, 34059, 34066-34068, 34072.

DIAGNOSIS. As for genus.

DESCRIPTION. Long, straight to gently curved, irregular biserial trace, without closing loops, up to 18mm outer width, 8mm inner width. Internal organisation complex of subparallel track sets of up to 3 pairs of variable length transverse ridges, each of which may be distally bifurcate or trifurcate, with short, very fine longitudinal striae perpendicular to their length. Length of individual ridges in each set increasing towards the margin of the track. Central zone of the track with up to 3 distinct or 2 axially connected, curved transverse ridges, or a series of up to 4 irregularly disposed oblique short ridges. On some specimens additional asymmetrical curved transverse ridges at the margins of the track. Individual pairs highly variable, but approach symmetry when the trace is nearly straight. Longitudinal striae, oblique and arcuate ridges sporadic along length of track, within the axial zone. In some specimens medial arcuate, symmetrical ridges, with tiny longitudinal striae with a series of adaxially disposed divergent ridges at their margins, and a number of lateral short marks fanning around the individual paired ridges.

REMARKS. There are a large number of biserial arthropod tracks superficially similar to this material, but most lack the internal variablity and complexity of this ichnotaxon, particularly within the track axis. *Diplichnites govenderi* Savage, 1971, lacks the flaring and branching of individual tracks, lacks medial ridges and is, in general, a simpler trace. The considerable variation in this genus reflects similar morphological variation encountered by Anderson (1975) in *Umfolozia* Savage, 1971, but *Umfolozia* bears appendage marks and sinuously arranged oval marks in the medial zone and lacks the complexity of medial arcs and branching ridges present in *Alphaichnus*.

Walter (1983) discussed many late Palaeozoic ichnotaxa attributed to arthropods. *Heterotripodichnus divaricatus* Walter and *H. longitarsalis* Walter approach the present material in complexity, but in both, the appendage marks are more longitudinally arranged within the trace.

Irregular morphology makes the identification of repeat distances difficult. Repetition of medial ridges is interspaced by 5 track pairs, which suggests minimum track repetition. Track pairs are interpreted as appendage marks with their distal bifurcations and other branchings representing the 2 roughly equally-sized rami. Medial oval and arcuate marks are interpreted as pleopod imprints and withdrawal marks. Longitudinal striae on the appendage marks setae. Distal fine arcuate marks are interpreted as traces of antennae.

The differing depth of track penetration displayed by the many slabs examined with undertracks suggests that substrate firmness was variable, but was high in the case of generation of this track compared to the occurrences of *Isopodichnus queenslandensis*.

Wadeichnus ichnogen. Nov.

TYPE SPECIES. *Wadeichnus maryae* ichnogen et ichnosp. nov.

ETYMOLOGY. For Mary Wade.

DIAGNOSIS. Biserial track of elongate, lobate, longitudinally disposed marks, consisting of up to 5 elongate striae, terminating in a horseshoe-shaped depression within which the striae fan slightly; with or without marginal arcuate ridges perpendicular to track axis, and with or without a bounding pair of longitudinal fine ridges.

Wadeichnus maryae ichnogen. et ichnosp. nov. (Figs 2C,D, 4, 5, 12C)

MATERIAL. HOLOTYPE: QMF39063. PARATYPES: QMF39065, 39061.

ETYMOLOGY. For Mary Wade.

DIAGNOSIS. As for genus.

DESCRIPTION. Biserial, somewhat discontinuous track, up to 14mm wide, of symmetrical or subsymmetrical lobate marks, up to 8mm long, of 3-5 longitudinal striae which diverge slightly within a horseshoe-shaped depression, accompanied by marginal fine ridges, papillate, which are perpendicular to the trace axis and a pair of longitudinal fine threads at the margin of the trace. Some specimens show a central thread running lengthwise along the trace. In two specimens the orientation of the appendage marks (striae sets) are oblique to the trace axis.

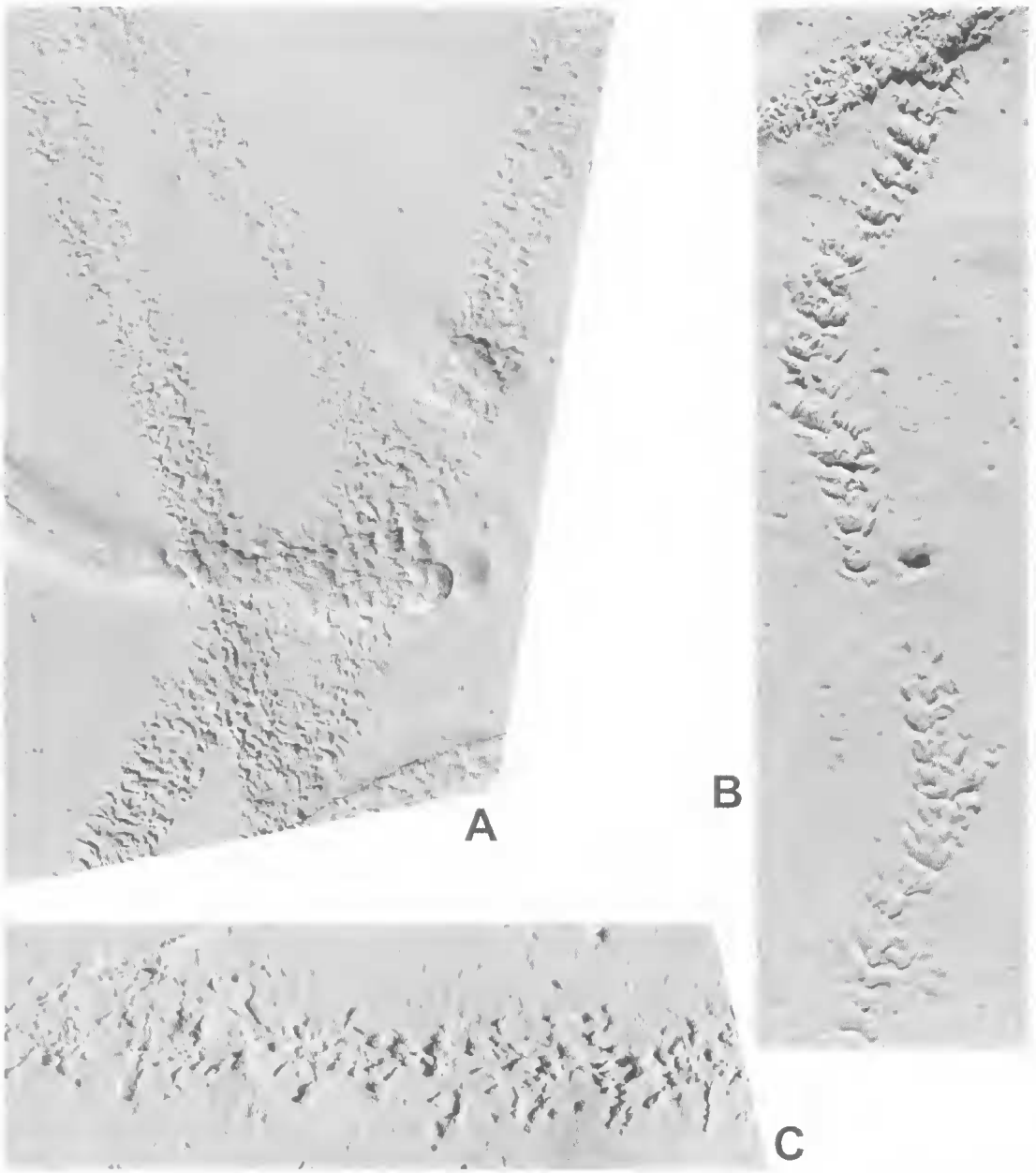

FIG. 9. A, *Alphaichnus alphaensis* ichnogen. et ichnosp. nov. QMF32231 × 1. B, C, cf. *Alphaichnus*. QMF34036 and F39064 respectively.

REMARKS. The arcuate ridges perpendicular to the axis are interpreted as antennae marks elongate striation pairs as pleopod marks and horseshoe depressions (in hyporelief) interpreted as withdrawal markings (sensu Osgood, 1970). The sporadically present central thread may be a telson drag mark. It is likely that the specimen assigned to cf. *Alphaichnus* (Fig. 9B,C) is transitional between *Alphaichnus* and this ichnotaxon. *Wadeichnus* probably was formed on a semifirm substrate with only minimal contact of the arthropod body and the surface sediment.

FIG. 10. *Alphaichnus alphaensis* ichnogen. et ichnosp. nov. QMF39068 ×1.

indet. appendage marks
(Fig. 7B)

MATERIAL. QMF34067.

DESCRIPTION. Small elongate series, 11mm long and 5mm wide of arcuate or lunulate to v-shaped wrinkle marks in hyporelief, up to 6 in an individual series, with discontinuous sets in close association.

REMARKS. These marks probably represent asymmetrical appendage falls upon the substrate with subsequent, but penecontemporaneous plastic deformation, probably on a low slope. The lack of material available and the unusual

FIG. 11. *Alphaichnus alphaensis* ichnogen. et ichnosp. nov. QMF34084, holotype (small arrow) part of composite slab, × 1. *Isopodichnus queenslandensis*, juvenile specimens (large arrow). Note the numerous indeterminate appendage marks (open triangles).

morphology prevents any accurate assignment. Anderson (1975) described bedding surface slump structures similar to those found in the Alpha material.

indet. paired appendage marks
(Fig. 11 (part))

MATERIAL. Part of slab with QMF34084.

DESCRIPTION. Almost all slabs containing *Wadeichnus* and *Alphaichnus* have isolated, shallow small paired or more rarely single holes (in epirelief). They are commonly triangular with one apex deeper, or they are subquadrate with no directional shallowing. Pairs are separated by 2-3mm. No continuity in sets of pairs can be identified.

REMARKS. We interpret these holes as appendage pluck-out or withdrawal marks

FIG. 12. A, *Alphaichnus alphaensis* ichnogen. et ichnosp. nov., and indeterminate 'sweep' mark, QMF34066 ×2. B, *Isopodichnus queenslandensis* ichnosp. nov. QMF39062, showing sinuosity, ×1. C, *Wadeichnus maryae* ichnogen. et ichnosp. nov. QMF39061 ×2. D, indeterminate scurry marks QMF39067 ×1.

associated with isolated substrate interactions. The association of these holes with the more complex traces shows differing behaviour between the maker of *Alphaichnus* and the originator of these marks, but we cannot determine whether it would be a similar animal.

indeterminate 'sweep' marks
(Fig. 6 (part))

MATERIAL. QMF34090

REMARKS. On a number of specimens are elongate curved and recurved ridges which lack repetitive association or are in groups of 1 or 2. These ridges are up to 25mm long, and <1mm thick, gently curved with a stepped weak bilateral symmetry, if at all. These structures are interpreted as sweep marks from some organism; they are much too small and non-persistant to be *Undichnia* (sensu Anderson, 1976; Buatois & Mangano, 1994) and are indeterminate. The material resembles *Stialia pillosa* Smith of Walker (1985), but lacks the abundant scratch marks.

indeterminate scurry marks
(Fig. 12D)

MATERIAL. QMF 39067.

REMARKS. Small, disordered set of weakly to strongly divergent ridges with an impersistent, marginal sinuous set of bordering threads. Imprints (ridges in hyporelief) are in groups of 3 or more and are short, sporadically divided and bear fine transverse striae. The specimen is interpreted as a set of arthropod pleopod marks where the pleopods bear setae and are probably biramal. The trace architecture is inferred as resulting from an arthropod scurrying across the firm substrate. The sinuous threads are interpreted as antennae marks.

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